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Experimental Investigation on Behaviour of Reinforced Concrete Beam Element Using Swimmer Bars as Shear Reinforcement

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Abstract: *A reinforced concrete beam may fail suddenly due to shear and therefore it is necessary to find some safe way to design the beam. The beams subjected to shear failure show different behaviour when compared with bending mode of failure. The width of cracks due to shear forces is more compared to bending forces. The shear failure may not give suitable warning before failure. Hence reinforcement has to be designed in a way that it can carry shear forces effectively. Previous studies show that swimmer bars are effective as shear reinforcement. Swimmer bar is a small bar inclined at some angle, and its either ends are bent horizontally for a small distance, it can be either welded or bolted accordingly, both at the top and bottom of flexural steel reinforcement. Due to the use of swimmer bars in an inclined plane, it forms plane-crack interceptor system, while in case of stirrups bar-crack interceptor system is formed. This study is done by using two different shapes of swimmer bars. The purpose of this study is to find the most efficient shape of reinforcement to carry shear forces and also maintaining the economy of the structure. Reinforced concrete beam elements are casted and tested. The Load-Deflection variation for each beam is also plotted at a particular load. A close monitoring is also done on both flexural and shear cracks developed in the beam.*
Keywords*: Swimmer bar, Shear, Crack, Deflection, Stirrups.*

I. Introduction

A beam is usually a horizontal structural element that can resist lateral loads in a structure. A Beam deflects primarily due to bending. A beam is subjected to bending moments and shearing force, when external loads are acting on it. Such a beam bends or undergoes deformation. The cross section of the beam will offer resistances to bending moments and shear forces and these resistances are called bending stresses and shearing stresses respectively. Beams can be classified based on their type of support, shape of the cross-section, length, and the material used.

Stresses induced in the beams:

Shear Force

Shear force at any cross section of a loaded beam is defined as the unbalanced vertical force at that section. Mathematically, shear force is calculated as the algebraic sum of all the vertical forces on one side of the section..

Bending Moment

The bending moment at any section of a loaded beam is the algebraic sum of moments of all the loads about that section considering either right or left of that section.

Loads acting on beams:

A beam usually carries vertical loads, but it can also carry inclined loads based on the situation.
The following are the types of loads.

- Point load or concentrated load [PL].
- Uniformly distributed load [UDL].

- Uniformly varying load [UVL].

Types of failures in reinforced concrete beams:

Flexure Cracks – due to bending moments
Shear Cracks – due to shear forces
Torsional Cracks – due to twisting moments
Corrosion Cracks – due to corrosion of steel reinforcement
Shrinkage Cracks – due to plastic shrinkage of concrete

II. Material And Methods

In this project, we replace the conventional shear reinforcement with modified swimmer bars and inclined stirrups, using welded connection and two different shapes are used.

Types of shear reinforcement used:

Conventional stirrups

Conventional stirrups are also called as vertical stirrups, provided as two legged or four legged stirrups bend around the tensile reinforcement and taken to the compression zone and anchored to the hanger bars. They are generally used for holding longitudinal reinforcement in position. Diagonal tensile stress is caused by shear and bending, there by forming cracks. Hence to prevent this stirrups are used.They are tied to main reinforcement bars with binding wires, stirrups also connect the top and bottom reinforcement along the length of the beam.

Figure 1: Conventional stirrups

Swimmer bars

A swimmer bar is a small steel bar inclined at some angle. Its either ends are bent horizontally for a small distance, it can be either welded or bolted accordingly, both at the top and bottom of flexural steel reinforcement. The main advantage of this swimmer bars is that, the area of steel required is less. Swimmer bars are also known to increase shear resistance, reduce the dimensions of the cracks, also resist the deflections.

I-Shaped welded swimmer bars

I-Shaped swimmer bars are also called as single swimmer bars, these are the I-shaped bars welded to the main and longitudinal bars at an angle generally 45°. They are used as a replacement of shear stirrups to act as shear reinforcement in the beam.

Figure 2: I-shaped welded swimmer bars

Rectangular welded swimmer bars

Rectangular swimmer bars are also called as double swimmer bars, there are two types of rectangular swimmer bars, simple rectangular swimmer bars and Rectangular swimmer bars with cross bracings. These swimmer bars are welded inclined to the main and longitudinal reinforcement in the beam.

Figure 3: Rectangular welded swimmer bars

Materials used for casting of beams

Table no 1: This show the materials used in this project

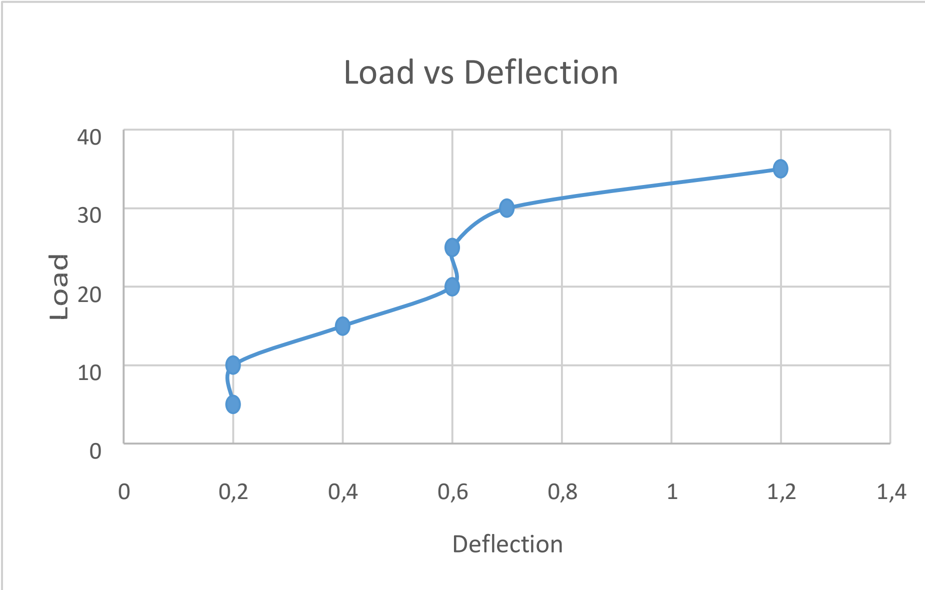
Material	Remarks
Cement	OPC 53 Grade, Zuari Cement
Steel	HYSD 10 mm, 6mm ∅ bars
Fine Aggregate	IS 4.75 mm passing and retained on 75μ
Coarse Aggregate	20 mm passing and retained on 16.5 mm and 12.5mm passing and retained on 1. mm
Water	Potable water

III. Results and Discussion

Beams with conventional shear reinforcement 14 days curing

Table no 2: Results of conventional stirrups 14 days curing

S.No	Load	Deflection (mm)	Stress
1	5	0.2	0.34
2	10	0.2	0.67
3	15	0.4	1
4	20	0.6	1.34
5	25	0.6	1.67
6	30	0.7	2
7	35	1.2	2.33

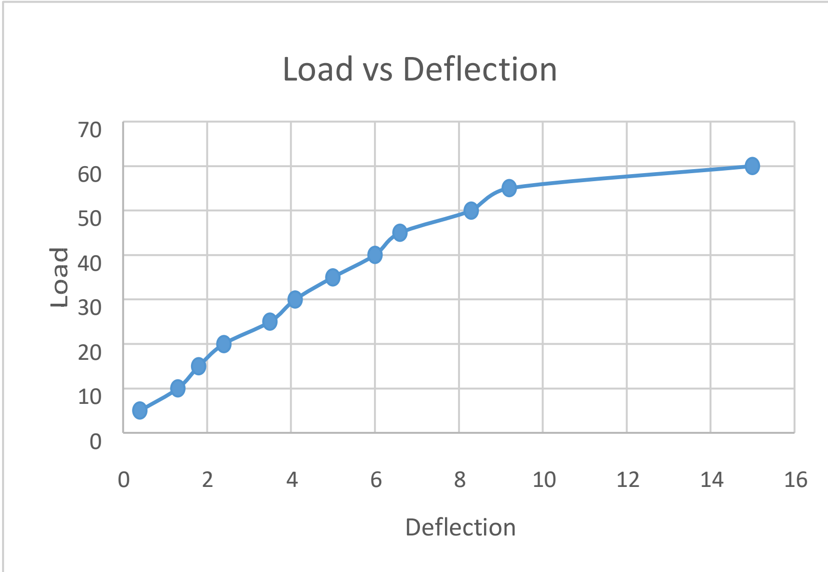


The above graph represents the Deflections of the beam for the loads applied, the beam failed at support due to the insufficient support distance. The failure load of the beam is 41.64KN with the maximum deflection of 1.2mm.

Beam with I-shaped welded swimmer bars as shear reinforcement 14 days curing

Table no 3: Results of beam with I-Shaped welded swimmer bars 14 days curing

S.No	Load	Deflection (mm)	Stress
1	5	0.4	0.34
2	10	1.3	0.67
3	15	1.8	1
4	20	2.4	1.34
5	25	3.5	1.67
6	30	4.1	2
7	35	5	2.33
8	40	6	2.67
9	45	6.6	3
10	50	8.3	3.33
11	55	9.2	3.67
12	60	15	4

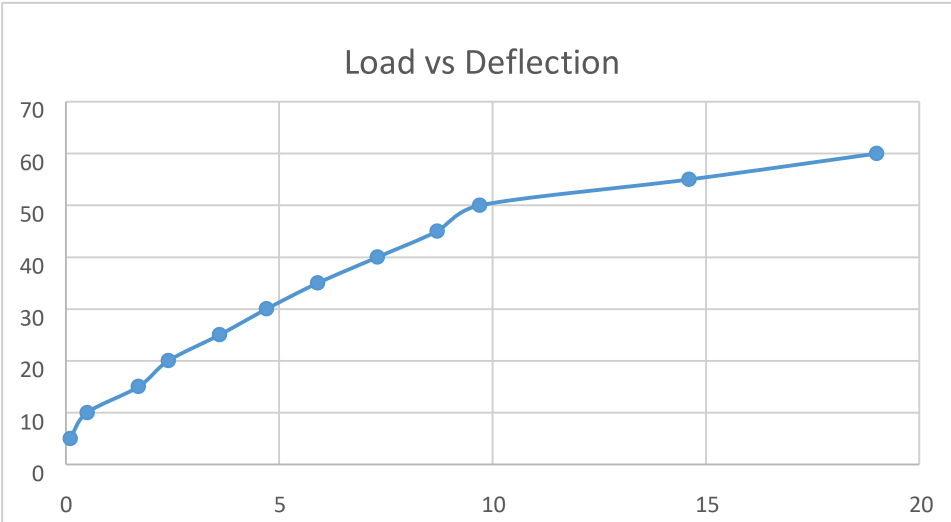


The above graph represents the Deflections of the beam for the loads applied, the beam failed by flexural failure with cracks in the mid span of beam. The failure load of the beam is 68.15KN with the maximum deflection of 26.5mm.

Beam with rectangular welded swimmer bars as shear reinforcement 14 days curing

Table no 4: Results of beam with Rectangular welded swimmer bars 14 days curing

S.No	Load	Deflection (mm)	Stress
1	5	0.1	0.34
2	10	0.5	0.67
3	15	1.7	1
4	20	2.4	1.34
5	25	3.6	1.67
6	30	4.7	2
7	35	5.9	2.33
8	40	7.3	2.67
9	45	8.7	3
10	50	9.7	3.33
11	55	14.6	3.67
12	60	19	4



The above graph represents the Deflections of the beam for the loads applied, the beam failed by flexural failure with cracks in the mid span of beam. The failure load of the beam is 62.87KN with the maximum deflection of 28mm.

Comparison of flexural strength of beams

Table no 5: Comparison of flexural strength of beams

Type of shear reinforcement in beam	**Load at failure (KN)**	**Flexural strength(N/mm^2)**	**Type of failure**
Conventional stirrups	41.64	20.35	Support failure
I-Shaped welded bars	68.15	33.31	Flexure failure
Rectangular welded swimmer bars	62.87	30.73	Flexure failure

Comparison of deflections of beams

Table no 6: Comparison of Deflections of beams

Type of reinforcement in beam	**Flexural Strength (KN)**	**Maximum Deflection(mm)**
Conventional stirrups	40	13
I-Shaped swimmer bars	60	15
Rectangular swimmer bars	60	19

Comparison of shear strength of beams

Table no 7: Comparison of Shear strength of beams

Type of reinforcement in beam	Load at failure(KN)	Shear strength(N/mm^2)
Conventional stirrups	41.64	1.5
I-Shaped swimmer bars	68.15	2.4
Rectangular swimmer bars	62.87	2.3

IV. Conclusion

Shear cracks and flexural cracks are developed in beams with conventional stirrups, shear cracks are at an angle of 45°. In case of beams with I-Shaped and rectangular welded swimmer bars only flexural cracks were developed but no shear cracks. Beam with I-Shaped swimmer bars has undergone less deflection when compared to rectangular welded swimmer bars and conventional stirrups. Area of steel for beams with I-Shaped welded swimmer bars is 39% less compared to that of beams with rectangular welded swimmer bars and conventional stirrups. Shear strength of beams with inclined swimmer bars is almost 50% more than that of beams with conventional stirrups.

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